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Summer Program Scheduling at the Air Force Academy

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Summer Scheduling at the United States Air Force Academy

75th MORS Symposium

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Problem Statement



- To create a better system to schedule USAFA cadets into **summer programs**.
 - Summers consist of three, 3-week periods
 - Programs include a mixture of operational tours, USAFA leadership programs, and leave
- Previous scheduling process utilized an heuristic that left **many cadets unscheduled**.



Overview



- Information about summer programs
- The old scheduling process
- Integer programming approach
- Computational results
- Future work



Summer Schedules

Rising So, Jr, Sr Cadets



2nd Summer

Operation Non-Com
Airmanship Program
Global Engagement
Leave

3rd Summer

Operation 3rd Lt
USAFA Leadership
Leave

4th Summer

Operation Brevet Lt
USAFA Leadership
Leave

- The order of the three (or four) courses will vary by cadet
- For rising sophomores, global engagement is always scheduled opposite airmanship program
- Airmanship programs (soaring and jump) have limited enrollment in each summer period



Summer Schedules



- More than 3,000 cadets (approx. 1,000 per class)
- Nearly 50 summer programs
 - Four major categories:
 - Airmanship
 - Leadership
 - Summer Operations (e.g., Operation Air Force)
 - Leave



Old Scheduling Process

Data Collection



- Summer programs office begins gathering data in **early October**
 - Enrollment quotas
 - “Cadre” (i.e., cadet leader) quotas
 - Pre-scheduled cadet information
 - Program staff
 - Intercollegiate athletes
 - Flying team members
 - Late graduates
 - “Must-have” leave requests
 - Cadet preferences for programs and for leave period
- Inputs are **extremely fluid** and often not received by deadline



Old Scheduling Process

The Heuristic



- Load pre-scheduled cadets into course/offering
- Select course/offering as follows (for sophomores):
 - Leave
 - Courses with fewer than 3 offerings
 - Airmanship and Global Engagement
 - Others (fewest offerings first)
- Cadets **randomly selected**, assigned if course is preferred and cadet is available
- Cycle to next cadet until course/offering is full
- Cycle to next course/offering, continue random cadet selection



Old Scheduling Process Results



- Nearly **6-month** process
- Heuristic had **only a 60% initial success rate** (~1,800 cadets feasibly scheduled each year)
 - Remainder incompletely or incorrectly scheduled
 - These must be completely scheduled by hand
 - Some schedules must be re-worked due to new/changing requirements or cadet circumstances
- **Little consideration given to cadet preferences** or cadet ranking (e.g., Overall Performance Average)



Toward a New Model



■ Approach:

- Integer programming model
 - Single IP model for the sophomores
 - Combined IP model for the juniors and seniors

■ Goals:

- Shorter running time, allows repeated runs and sensitivity analysis
- Greater number of cadets scheduled to reduce the amount of manual re-work
- Greater cadet satisfaction



Cadet Preferences



- Cadets indicate their **primary** and **alternate** choices for:
 - Leave
 - Airmanship (for sophomores)
 - Leadership (for juniors and seniors)
- **Relative value** of leave versus airmanship programs:
 - Specified by summer programs office
 - Affected by cadet's Overall Performance Average (OPA)
 - Objective function **value** associated with assigning a cadet to his/her primary or alternate choice given by:

	Leave	Airmanship
Primary	100*OPA	50*OPA
Alternate	10*OPA	25*OPA



Mapping Programs to Time Slots



■ Indicators (based on known data):

$$\delta_p^t = \begin{cases} 1 & \text{if program } p \text{ is scheduled during time slot } t = 1, \dots, 6 \\ 0 & \text{otherwise} \end{cases}$$

■ Example:

- MilTng 444AC -- Leave is scheduled for first period (i.e., time slots 1 and 2).

Time Slot	Delta
1	1
2	1
3	0
4	0
5	0
6	0



Decision Variables



- Let **C** be the set of cadets
- Let **P** the set of programs
 - Each program occurs once, e.g., Leave during first period is a ***different program*** from Leave during second period
- Decision Variables:

$$x_{cp} = \begin{cases} 1 & \text{if cadet } c \text{ is assigned to program } p \\ 0 & \text{otherwise} \end{cases}$$



IP Formulation



$$\max \sum_{c \in C} \sum_{p \in P} value_{cp} \cdot x_{cp}$$

Maximize overall value of assigning cadets to programs

Subject To:

$$\sum_{p \in P} \delta_p^t \cdot x_{cp} = 1 \quad \forall c \in C, t \in \{1, \dots, 6\}$$

Each cadet has one program scheduled in each period

$$\sum_{c \in C} x_{cp} \geq \min_p \quad \forall p \in P$$

$$\sum_{c \in C} x_{cp} \leq \max_p \quad \forall p \in P$$

Number of cadets assigned to each program must lie within upper and lower enrollment limits for that program



IP Formulation



$$\sum_{p \in P_{Ops}} x_{cp} = 1 \quad \forall c \in C$$

Each cadet assigned to one Ops program

$$\sum_{p \in P_{Leave}} x_{cp} = 1 \quad \forall c \in C$$

Each cadet assigned to one Leave program

$$\sum_{p \in P_{Airmanship}} x_{cp} = 1 \quad \forall c \in C$$

Each cadet assigned to one Airmanship program

$$\sum_{p \in P_{GE}} x_{cp} = 1 \quad \forall c \in C$$

Each cadet assigned to one Global Engagement

$$x_{cp} \in \{0,1\} \quad \forall c \in C, \forall p \in P$$

Decision variables are binary

Jr/Sr model replaces Airmanship and Global Engagement constraints with Leadership program constraints



Additional Constraints



- Incorporating double-period (six week) programs
- Handling pre-scheduled cadets
- Cadet must not enroll in a particular program
- Cadet must not enroll in a particular type of program (e.g., Ops, Leave, Leadership, or Airmanship)
- Under- or over-filling courses
 - We use slack/surplus variables and penalties to guarantee a feasible solution, but at a cost



Proof of Concept

Summer, 2004



- Model tested (but not used) for summer 2004
- Tested against rising sophomore class data
- 1114 cadets to schedule
- Required programs:
 - Leave
 - Global Engagement / Airmanship
 - Combat Survival Training

Number of Cadets	Automated Heuristic	Optimization Model
Missing Leave	3	0
Missing Global Engagement	13	0
Missing Combat Survival Training	117	0
Missing Airmanship Program	174	0
Missing Required Program (Total)	308 (27%)	0
Scheduled to 1 st Leave Period Preference	972 (87%)	1022 (92%)
Time to Produce Feasible Schedules	weeks	hours (including pre-processing)

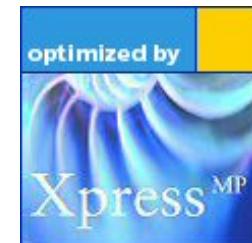
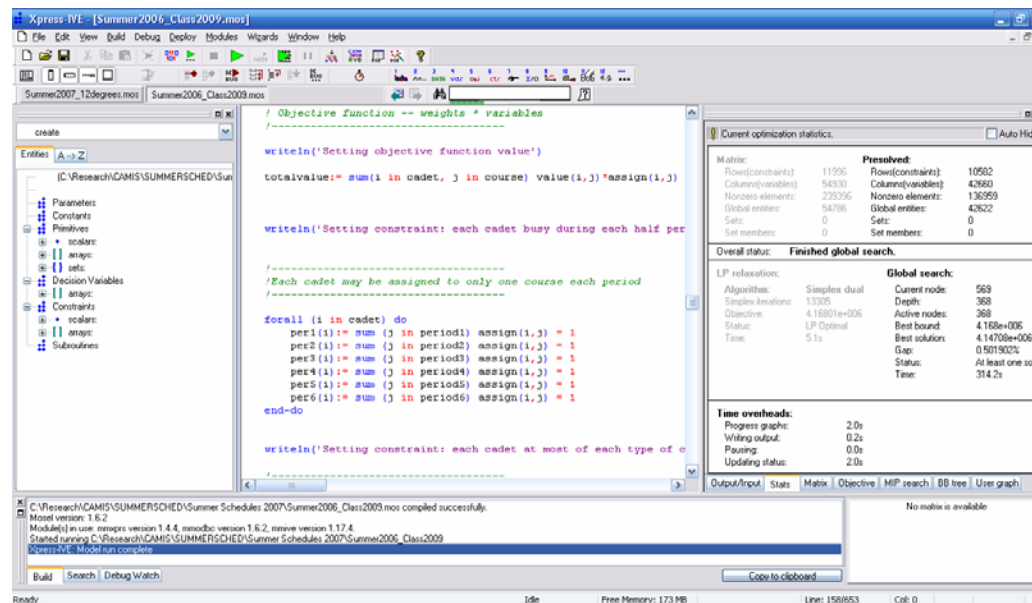
** Work of Hendricks, Fear, and Perkins*



Implementation



- Coded using Xpress-MP v2004, later ported to v2006



- Data input/output via Excel, text file, and SQL interface
 - Data source is the Cadet Administrative Management Information System (CAMIS – an Oracle Database)



Implementation



- Success with 2004 test led to model development, refinement, and use for 2005, 2006, and 2007 schedules
 - Significant changes to summer program process occurred during each year
 - Required and optional programs changed
 - Program substitutes allowed to fill requirements
 - Validated model flexibility & robustness
 - Changes handled by modifying the input data



Results Previous Years



■ Summer 2005:

- ~99.5% successfully scheduled
- Only 13 of 3000+ schedules incomplete or incorrect (required re-work by hand)
 - Due primarily to conflicting requirements, (e.g. “must-have” leave and “pre-sched” program)
- Historically, more than 1,000 re-works necessary annually

■ Summer 2006:

- Focused on model clean-up for long-term use
- Same benefits to the summer programs office



Results Summer 2007



■ Sophomore Model:

- 8-10 minutes (5.5 sec for LP relaxation, rest of the time in Branch and Bound)
- LP optimality gap: 11%, reduced to less than 1% in 40 seconds
- 12,000 rows, 55,000 columns
- 1122 of 1138 received **first leave preference** (99%)
- **Zero** unscheduled cadets; manual review indicated no re-scheduling required



Results Summer 2007



■ Junior/Senior Model:

- 2.3 seconds (2.1 sec for LP relaxation)
- LP optimality gap: 0%
- 13,000 rows, 41,000 columns
- 78% received **first preference** for leave period, while 93% received **first or second preference** for leave period
- 13 of 2,192 cadets (1/2 %) required re-work
 - Caused by manual pre-scheduling errors
- Scheduling process for all three classes reduced from **two months** (pre-model) to **one week**



Future Work



- Develop **better methods to capture cadet program preferences** and personal trade-offs between programs
- **Implementation** into Cadet Administrative Management Information System (CAMIS)
 - Changing program requirements make this difficult
 - Anticipate a reduction in process time from one week to one day
- **Integration** with ***Operation Air Force*** scheduler
 - Summer program model provides the cadet-to-period assignments for the Ops AF program
 - Ops AF scheduler assigns cadets to specific bases



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